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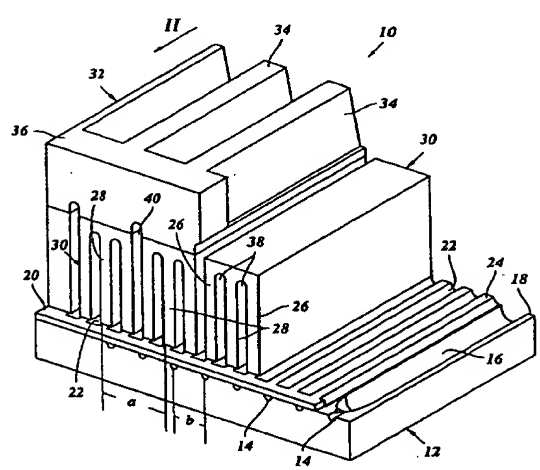
(54) **Ink jet nozzle head with multiple block structure**

(57) Ink jet nozzle head comprising:

- a channel plate (12) defining a linear array of equidistant nozzles (14) and a number of parallel ink channels (16) each connected to a respective one of the nozzles, and
- a comb-like array of fingers (26, 28) disposed on one side of the channel plate (12) such that the fingers project towards the nozzle plate,
- some of the fingers (26) being configured as actuators for exerting mechanical strokes on the ink contained in the ink channels, so as to expel ink droplets from the nozzles, at least one actuator being provided for each nozzle,
- the other fingers (28) serving as support members for supporting the actuators at the channel plate and receiving the reaction forces of the actuators,

characterized in that the fingers (26, 28) constitute a plurality of separate blocks (30), each block comprising one actuator (26) and one or two support members (28).

Fig. 1



EP 0 819 527 A1

Description

The invention relates to a nozzle head for use in an ink jet printer.

A nozzle head having the features specified in the preamble of claim 1 is disclosed in EP-A-0 402 172. This nozzle head comprises a channel plate defining a linear array of equidistant nozzles and a number of parallel ink channels each connected to a respective one of the nozzles. On one side of the channel plate there is disposed an array of elongate fingers projecting towards the nozzle plate and extending in parallel with the ink channels. The ends of these fingers facing away from the channel plate are interconnected by a plate-like backing member which is formed integrally with the fingers. The fingers and the backing plate are made of a piezoelectric ceramic material. Every second finger is provided with electrodes and serves as an actuator which, when a print signal is applied to the electrodes, compresses the ink liquid contained in the associated ink channel, so that an ink droplet is expelled from the nozzle. The other fingers intervening between the actuators serve as support members which are rigidly connected to the channel plate so that they can absorb the reaction forces generated by the actuators.

Since a support member is provided between each pair of consecutive actuators, each actuator is substantially shielded against the reaction forces from its neighbours, so that undesired cross-talk between the various channels is reduced.

However, when one of the actuators is activated, e.g. expanded, the support members adjacent thereto on both sides are elastically deformed to some extent, so that the backing plate is slightly deflected. This effect becomes more significant when a plurality of neighbouring actuators are activated simultaneously, so that the stresses applied to the backing plate are accumulated. In this case the deformation of the backing plate will also affect the actuators which are disposed at a comparatively large distance from the active actuators and will cause the generation of parasitic acoustic waves in the ink channels where no droplets are to be expelled. Thus, there exists a problem which can be termed "long-range cross-talk".

It is an object of the invention to provide a nozzle head in which long-range cross-talk can be suppressed more efficiently.

This object is achieved with the features indicated in claim 1.

According to the invention, the array of fingers is divided into a number of separate blocks, and each block comprises only one support member and only one or two actuators.

As a result, the reaction forces of the actuator or actuators of one block are directly absorbed by the support member of the same block and are confined to this particular block, so that they will have no substantial effect on the other blocks. Thus, the undesired long-range cross-talk phenomenon is largely eliminated.

The use of not more than two actuators per block has the advantage that the spatial configuration of the actuators in relation to the support member and the borders of the block is the same for all actuators of the array (except for mirror symmetry in case of two actuators disposed on both sides of the support member). Thus, the subdivision of the array of fingers into separate blocks will not cause any differences in the performance of the actuators during the process of droplet generation.

More specific features of the invention are indicated in the dependent claims.

In a preferred embodiment, each block has two actuators disposed on either side of the support member. This has the advantage that the density with which the fingers (actuators and support members) are arranged in the direction of the linear nozzle array is only 3/2 of the density of the nozzles. As a result, when the density of the nozzles is reduced for enhancing the resolution of the print head, the pitch of the fingers remains comparatively large which facilitates the manufacture of the array of fingers.

In this embodiment, there may occur a certain amount of cross-talk between the two channels associated with the same block. However, since the number of different energizing patterns which have to be considered in this case is small, an electronic compensation of the cross-talk by appropriately controlling the voltages applied to the actuators is greatly facilitated. In fact, only two cases have to be taken into consideration, i.e. (a) the case in which only one of the two actuators in energized and (b) the case in which both actuators of the block are energized. For compensating the cross-talk in these two cases, it is therefore sufficient to provide two different sets of voltages to be applied to the two actuators.

The array of fingers may be additionally supported by a separate backing member disposed on the side of the array opposite to the channel plate and extending over all the blocks. This backing member should however have a comparatively high flexibility, so that the mechanical coupling between the various blocks is limited to a tolerable amount. More preferably, the backing member has an anisotropic rigidity, such that it is comparatively stiff in the direction in parallel with the ink channels but is rather flexible in the direction transverse to the ink channels. This can be achieved for example by a grid-like backing member having a number of beams extending longitudinally of the ink channels and each being disposed over one of the blocks.

Preferred embodiments of the invention will now be described in conjunction with the accompanying drawings, in which:

Fig. 1 is a partly broken-away perspective view of a nozzle head according to a first embodiment of the invention;

Fig. 2 is a cross-sectional view in the direction of

the arrow II in Fig. 1; and

Fig. 3 is a view similar to Figure 2 but showing a second embodiment of the invention.

The nozzle head 10 illustrated in Figures 1 and 2 comprises a channel plate 12 which defines a linear array of nozzles 14 and a number of parallel ink channels 16 only one of which is shown in Fig. 1. The nozzles 14 and the ink channels 16 are formed by grooves cut into the top surface of the channel plate 12. Each nozzle 14 is connected to an associated ink channel 16. The ink channels are separated by dam portions 18, 18'.

The top sides of the nozzles 14 and the ink channels 16 are closed by a thin vibration plate 20, which is securely bonded to the dam portions of the channel plate.

The top surface of the vibration plate 20 is formed with a series of grooves 22 which extend in parallel with the ink channels 16 and are separated by ridges 24. The ends of the grooves 22 adjacent to the nozzles 14 are slightly offset from the edge of the vibration plate 20.

An array of elongate fingers 26, 28 is disposed on the top surface of the vibration plate 20 such that each finger extends in parallel with the ink channels 16 and has its lower end fixedly bonded to one of the ridges 24. The fingers are grouped in triplets, each triplet consisting of a central finger 28 and two lateral fingers 26. The fingers of each triplet are interconnected at their top ends and are formed by a one-piece block 30 of piezoelectric material.

Each of the fingers 26 is associated with one of the ink channels 16 and is provided with electrodes (not shown) to which an electric voltage can be applied in accordance with a printing signal. These fingers 26 serve as actuators which expand and contract in vertical direction in response to the applied voltage, so that the corresponding part of the vibration plate 20 is deflected into the associated ink channel 16. As a result, the ink liquid contained in the ink channel (e.g. hot-melt ink) is pressurized and an ink droplet is expelled from the nozzle 14.

The central fingers 28 are disposed over the dam portions 18 of the channel plate and serve as support members which absorb the reaction forces of the actuators 26. For example, if one or both actuators 26 belonging to the same block 30 are expanded, they exert an upwardly directed force on the top portion of the block 30. This force is largely counterbalanced by a tension force of the support member 28 the lower end of which is rigidly connected to the channel plate 12 via the ridge 24 of the vibration plate.

The top ends of the blocks 30 are flush with each other and are overlaid by a backing member 32. The backing member 32 is formed by a number of longitudinal beams 34 extending in parallel with the ink channels 16 and by transverse beams 36 which interconnect the ends of the longitudinal beams 34 (only one of the transverse beams is shown in Fig. 1).

The longitudinal beams 34 have a trapezoidal cross section and are originally interconnected with each other at their broader base portions, so that they form a continuous plate. In a subsequent manufacturing step, a comparatively thick layer of piezoelectric material which will later form the blocks 30 is bonded to the plate, i.e. the lower surface of the backing member 32 in Fig. 1. Then, the blocks 30 and the fingers 26, 28 are formed by cutting grooves 38, 40 into the piezoelectric material. While the grooves 38 which separate the fingers 26 and 28 terminate within the piezoelectric material, the grooves 40 separating the blocks 30 are cut through into the backing member 32, thereby separating also the longitudinal beams 34 from one another.

Thus, the width of the longitudinal beams 34 is essentially equal to the width of the individual blocks 30. As a consequence, the beams 34 efficiently prevent an elastic deformation of the top portions of the blocks 30 when the actuators 26 expand and contract.

Since the support members 28 inevitably have a certain elasticity, expansion of one or both actuators 26 of one of the blocks 30 will also cause a minor expansion of the support members 28 and will tend to cause a slight deflexion of the backing member 32. If the backing member were a non-profiled flat plate, this deflective force would be transmitted to the neighbouring blocks 30 and would lead to the generation of parasitic acoustic waves in the neighbouring ink channels (cross-talk). Such long-range cross-talk may cause problems, especially when a large number of actuators in neighbouring blocks 30 are energized simultaneously. However, since the backing member 32 is formed by separate beams 34 which are only interconnected at their opposite ends by the transverse beams 36, and these transverse beams are additionally weakened by the grooves 40, the deflective forces are essentially confined to the blocks 30 from which they originate. Thus, the long-range cross-talk phenomenon can be suppressed successfully.

The subdivision of the array of fingers 26, 28 into separate blocks 30 each consisting of only three fingers also facilitates the further suppression of short range cross-talk, i.e. cross-talk between the ink channels associated with the same block 30. To this end, it is sufficient to make a distinction between two cases: (a) only one of the two actuators 26 is energized; (b) both actuators are energized. In the case (b) the support member 28 will be subject to a larger elastic deformation than in the case (a). This effect can easily be compensated by slightly increasing the voltage applied to the actuators in the case (b). It should be noted that this measure will not lead to an increased long-range cross talk, because the blocks 30 are separated from each other.

Conversely, in the case (a), the top portion of the block 30 and the beam 34 will be caused to slightly tilt about the top end of the support member 28, thereby compressing the ink in the neighbouring channel. This

effect will however be very small, thanks to the stabilizing effect of the transverse beams 36. If necessary, this minor effect can also be compensated by applying a small compensation voltage with appropriate polarity to the actuator associated with the non-firing channel.

Since the support members 28 are made of piezoelectric material, it is also possible to provide additional electrodes for the support members 28 in order to actively counterbalance the reaction forces of the actuators 26.

In the shown embodiment, the width of the grooves 40 is identical to the width of the grooves 38, and the fingers 26, 28 are arranged equidistantly. The pitch a of the support members 28 is larger than the pitch b of the nozzles 14 by a factor 2. Since every third finger is an actuating member 28, the pitch of the fingers 26, 28 is 2b/3, in comparison to a pitch of b/2 for the conventional case in which a support member is provided between each pair of adjacent ink channels. As a result, the pitch b of the nozzles and hence the resolution of the print head can be made small without exceeding the limits imposed by the manufacturing process for the piezoelectric actuators and support members.

In a practical embodiment the pitch b of the nozzles 14 may be as small as 250 m (i.e. four nozzles per millimeter). The pitch of the support members 28 will accordingly be 500 m, and the pitch of all fingers (including the actuators 26) will be 167 m. In this case, the width of each individual finger 26 or 28 may for example be 87 m, and the grooves 38, 40 will have a width of 80 m and a depth in the order of 0,5 mm.

As is shown in Fig. 2, the grooves 22 and ridges 24 of the vibration plate 20 and the nozzles 14, the ink channels 16 are not evenly distributed over the length of the nozzle array. Instead, the ink channels 16 are grouped in pairs separated by comparatively broad dam portions 18, whereas the ink channels of each pair are separated by a comparatively narrow dam portion 18'. The broad dam portions 18 coincide with the ridges 24 of the vibration plate and with the support members 28, whereas the smaller dam portions 18' coincide with the grooves 22 of the vibration plate and the grooves 40 between the blocks 30. The width of the ink channels 16 (at the top surface of the channel plate 12) is larger than the width of the fingers 26, 28, and the ink channels are offset relative to the nozzles 14 to such an extent that none of the actuators 26 overlaps with the dam portions 18, 18'.

The portions of the vibration plate 20 on both sides of the ridges 24 which are held in contact with the actuators 26 are weakened by the grooves 22, and at least a major part of these weakened portions is still within the area of the ink channels 16. Thus, the vibration plate 20 can readily be flexed into the ink channel 16 in response to expansion strokes of the actuators 26. The width of the ridges 24 is slightly smaller than that of the fingers 26, 28.

With the above configuration an excessive bending or shearing stress in the vibration plate 20 near the edges of the dam portions 18, 18' is avoided, so that a high durability of the vibration plate 20 can be achieved.

The vibration plate 20 may be formed by a relatively soft foil of polyimide resin which is welded to the channel plate 12 and the ends of the fingers 26, 28. Alternatively, the vibration plate may be formed by a thin film of glass or metal (aluminum) which is soldered to the channel plate and the fingers.

While a specific embodiment of the invention has been described above, it will occur to a person skilled in the art that various modifications can be made within the scope of the appended claims.

For example, the width of the actuators 26 may be different from that of the support members 28. Likewise, the width of the grooves 40 may be different from that of the grooves 38, resulting in an uneven distribution of the fingers 26, 28.

Figure 3 shows an embodiment in which there is a one-to-one relationship between the support members 28 and the nozzles 14, and each block 30 consists only of two fingers, i. e. one support member 28 and one actuator 26. The ink channels 16 are arranged equidistantly, without being offset relative to the corresponding nozzles 14. The vibration plate 20 has a uniform thickness.

Claims

1. Ink jet nozzle head comprising:

   - a channel plate (12) defining a linear array of equidistant nozzles (14) and a number of parallel ink channels (16) each connected to a respective one of the nozzles, and
   - a comb-like array of fingers (26, 28) disposed on one side of the channel plate (12) such that the fingers project towards the nozzle plate,
   - some of the fingers (26) being configured as actuators for exerting mechanical strokes on the ink contained in the ink channels, so as to expel ink droplets from the nozzles, at least one actuator being provided for each nozzle,
   - the other fingers (28) serving as support members for supporting the actuators at the channel plate and receiving the reaction forces of the actuators,

   characterized in that the fingers (26, 28) constitute a plurality of separate blocks (30), each block comprising one actuator (26) and one or two support members (28).

2. Nozzle head according to claim 1, wherein the pitch (a) of the support members (28) is twice the pitch (b) of the nozzles (14), and each block (30) comprises two actuators disposed on opposite sides of the support member.

3. Nozzle head according to claim 1 or 2, wherein the fingers (26, 28) are evenly distributed over the length of the nozzle array.

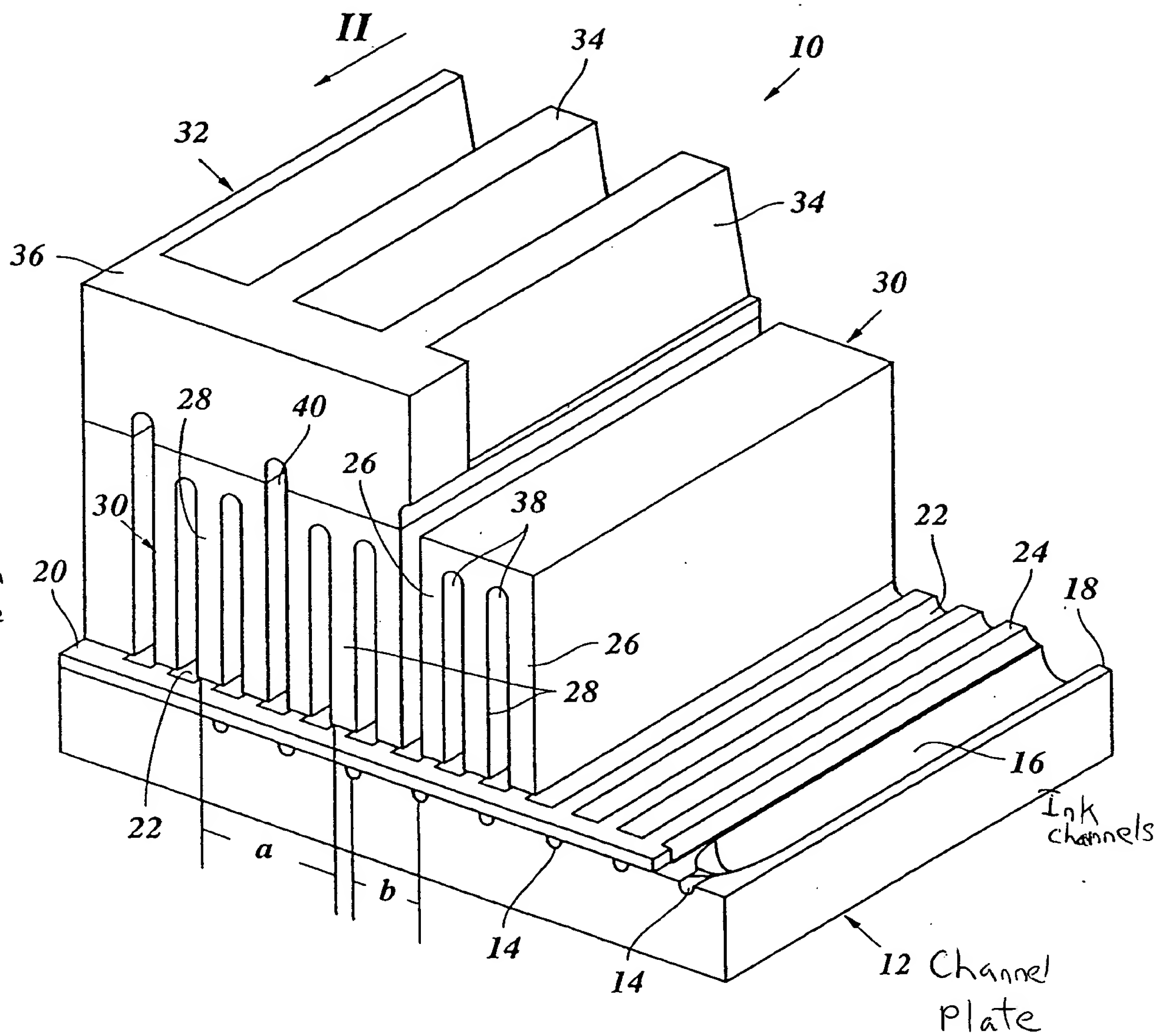
4. Nozzle head according to anyone of the claims 1 to 3, wherein the fingers (26, 28) are separated by grooves (38, 40), the grooves (38) provided between fingers of the same block having a smaller depth than the grooves (40) which separate different blocks.

5. Nozzle head according to anyone of the preceding claims, wherein the blocks (30) are overlaid by a separate backing member (32) which has a higher flexibility in the transverse direction of the ink channels (16) than in the longitudinal direction thereof.

6. Nozzle head according to claims 4 and 5, wherein the the grooves (40) separating the blocks (30) are extended into the backing member (32).

7. Nozzle head according to claim 5 or 6, wherein the backing member (32) comprises a number of beams (34) extending in longitudinal direction of the ink channels (16) and respectively disposed over each of the blocks.

Fig. 1


II
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Vibration Plate
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Ink channels
a
b
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14
12 Channel plate

Fig. 2

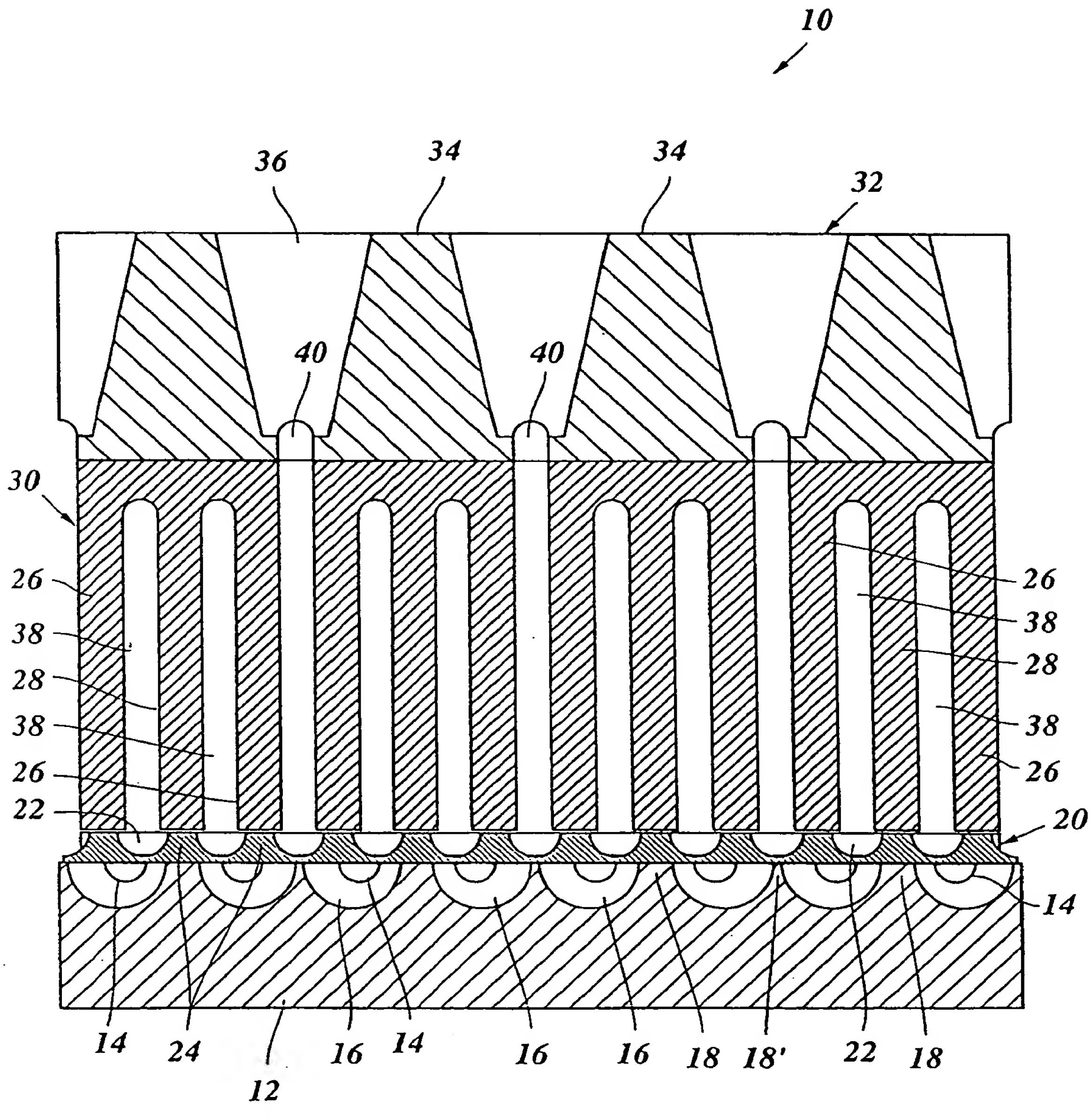
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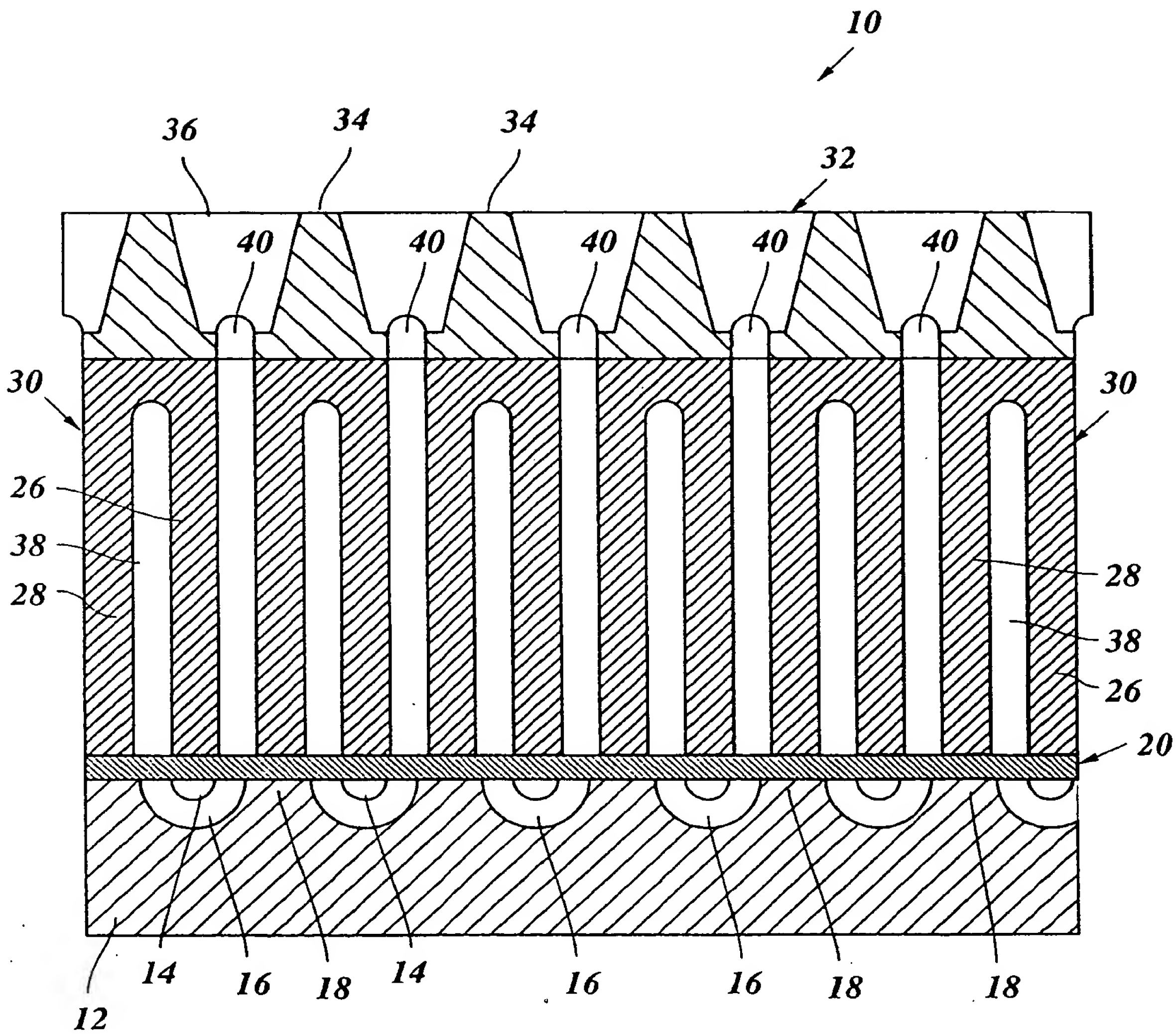
Fig. 3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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 20 2040

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	EP 0 402 172 A (SHARP KABUSHIKI KAISHA) * column 4, line 17 - column 5, line 24; figure 4 *	1,3	B41J2/045 B41J2/14
A	DE 36 30 206 A (FUJI ELECTRIC CO., LTD.) * claim 14; figure 1 *	1	
A	DE 195 11 408 A (SEIKO EPSON CORP.) * page 5, line 34 - line 67; figure 6C *	1,3	
A	PATENT ABSTRACTS OF JAPAN vol. 16, no. 132 (M-1229), 3 April 1992 & JP 03 293143 A (RICOH CO LTD), 24 December 1991, * abstract *	1-3	
A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 256 (M-1413), 20 May 1993 & JP 04 371846 A (RICOH CO LTD), 24 December 1992, * abstract *	1,3	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 694 (M-1531), 17 December 1993 & JP 05 238009 A (SEIKO EPSON CORP), 17 September 1993, * abstract *	1,3	B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	28 July 1997	Ducreau, F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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